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THE MEXICAN BEAN BEETLE IN FLORIDA¹

A. N. TISSOT

Since its discovery in the East, in the vicinity of Birmingham, Alabama, in 1920, the Mexican bean beetle, *Epilachna varivestris* (Muls.) has been of much interest and concern to American entomologists and agriculturists. Presumably a native of the Mexican plateau, the beetle was first recognized in the United States in 1864, and Chittenden (1919) states that it did serious injury to wax beans in Colorado in 1883. The insect received little attention, however, and there are very few references to it in entomological literature prior to 1920. Since then the picture has changed completely. The beetle has been the subject of numerous studies and investigations, the results of which have filled hundreds of pages of literature. That the beetle is still considered of major importance is evidenced by the fact that Index V of *American Economic Entomology*, covering the years 1930-1934, contains 113 references to it, and Index VI for the period 1935-1939 contains 100 references.

During its early years in the East the Mexican bean beetle amazed everyone with the unprecedented rapidity of its spread. Howard (1924b) states that in 1921 the beetle spread north and east a distance of more than 200 miles and the next year it advanced more than 100 miles farther. By 1930 it had been discovered in all but seven of the states east of the Mississippi River. When the beetle became established in the East, under environmental conditions so different from those in its native home, entomologists began to conjecture as to the effect of climate upon it and to speculate regarding its ultimate range. There was considerable difference of opinion and the statements were often misleading and sometimes contradictory. Hinds (1920) stated that there were not any climatic or geographic barriers in the East to prevent the pest from spreading. Howard (1924a) said

¹Contribution from the Department of Entomology, Florida Agricultural Experiment Station, Gainesville, Florida.

that in time it undoubtedly would extend its range over most of the hilly portions of the United States east of the Mississippi River and was of the opinion that its spread from the original point of infestation in northern Alabama was accomplished mainly by flight, assisted by the prevailing winds. Graf (1925) constructed climographs for Mexico City, Albuquerque, New Mexico, and Springfield, Illinois, which differ widely as regards temperature and moisture. As the beetle was able to maintain itself successfully in these three places he concluded that temperature and moisture are not important factors in limiting the distribution of the insect. Other workers believed that these factors could have a very marked effect upon the beetle. Howard (1921) considered a temperature of 100° F. or over in dry weather to be very destructive and found later (1931) that the larvae were killed in a few minutes when in direct sunlight, if the shade temperature was above 90° F. Eddy and McAllister (1927) during the drought of 1925 noted limited areas of eradication of the beetle in South Carolina and the next year when the heat and drought were still more severe, they found on the eastern edge of the infested area an actual recession averaging about 35 miles. Thomas (1924) studying the beetle in Alabama, noted a natural control by heat during a hot spell when the temperature was 100° F. to 101° F. in the shade.

Among the first to study the Mexican bean beetle under controlled conditions were Marcovitch and Stanley (1930). They assumed that since the beetle is a native of the Mexican tablelands, which have a rather uniform, cool climate with low maximum temperatures, it must be best adapted to such conditions. Their breeding work showed that a temperature of 77° F. was most favorable for survival and that higher temperatures hastened development but produced greater mortality. Using a formula based on the temperature and precipitation relationships of the beetle, they predicted the probable future range of the insect in the United States. They predicted that the beetle would reach Florida by way of the Atlantic coast and believed that the climate of the northeastern and southern parts of the state would be favorable for it.

Landis and Plummer (1935) made a survey of the Mexican bean beetle in Mexico and carried on some life history studies near Mexico City. They found the insect widely distributed in the country and recorded it from elevations ranging from 3 to 8,845 feet. However, it was found most prevalent in the area delimited

by the 20° C. (68° F.) isotherm which follows quite closely the boundaries of the central plateau. At Mexico City, the beetle had a single generation a year and the average developmental period from egg to adult was 57 days. On the basis of these studies and their observations that the beetle was not particularly destructive there, they contended that contrary to the statement of Marcovich and Stanley, optimum conditions for the beetle are not found in the Valley of Mexico.

A review and summary of previous work on the ecology of the bean beetle was given by Sweetman (1932). He concluded that temperature and moisture are very important limiting factors in the economic distribution of the insect. He used relative humidity rather than precipitation as the measure of the moisture conditions of the environment, and gave more importance to temperature extremes, than had been given by other workers. His predictions regarding the probable ultimate distribution of the beetle agree fairly well with those of Marcovich and Stanley. He concluded that moisture conditions would be suitable for the beetle in the Gulf Coast region but believed that high summer temperatures would prevent economic damage in much of the area, including northern and central Florida. However, he considered that a narrow strip along the coasts of the northern half of Florida would be sufficiently favorable to permit occasional damage from the insect and the southern half of the state was believed favorable for greater damage by the pest.

A few years later the bean beetle appeared in Florida and thus made it possible to compare its actual behavior with the predictions made for it. The first known infestation of the beetle in the state was discovered in a garden at Monticello, May 20, 1933, by Fred W. Walker who collected numbers of the adult insects. It was presumed that the source of the infestation was at Thomasville, Georgia, which is about twenty miles north of Monticello. The infested beans were destroyed and apparently the infestation was eradicated as no evidence of the insect could be found later in the summer of 1933 and there were no further reports of the beetle from there for several years.

In July, 1937, Professor J. R. Watson and the writer observed a rather heavy infestation of the beetle in a garden at Florala, Alabama, just north of the state boundary and there were unconfirmed reports that it was present across the line in Florida. However, the second definite record of a Florida infestation was made July 11, 1938, when Mrs. A. S. Snider of Havana, in northern

Gadsden County, sent in to the Entomology Department an egg cluster and five larvae which she had collected in her garden. Four adults and a pupa were taken at Quincy, August 11, 1938, and specimens were taken on butter beans at Tallahassee, August 16, 1938. Since then the insect has become rather widely established in western Florida as is shown by the following records compiled from the records of the Florida State Plant Board, the records and correspondence of the Entomology Department of the Experiment Station, and the Insect Pest Survey Bulletin.

No new localities were infested in 1939, but reports from Havana indicated that the infestation there was becoming better established and a single record showed that the Tallahassee infestation still persisted. On April 9, 1940, A. H. Madden reported that adult beetles were appearing in considerable abundance in bean fields at Havana and later he reported the insect as fairly widespread throughout Gadsden County. Other records for 1940 are: Gretna (Gadsden Co.), April 26; Milligan (Okaloosa Co.), August 24; Marianna (Jackson Co.), August 29; and Greensboro (Gadsden Co.), October 14. The Gadsden County infestations remained active in 1941 and new infestations were discovered at Glendale (Walton Co.), August 6, and at River Junction (Gadsden Co.).

The year 1942 produced more records of the beetle than any previous year. Adults became active in Gadsden County bean fields in April, and specimens were taken at Tallahassee on June 10. On June 11, all stages of the insect were collected at Monticello and the beetle was reported to be present in several sections of Jefferson County. This year also produced the first known infestations of the bean beetle in the peninsular part of Florida. On May 7, a grower from Hawthorne, brought in to the Experiment Station a few dozen large bean beetle larvae which he had collected in his field of lima beans. Professor J. R. Watson visited the planting the same day, collected a few more larvae, and reported that the infestation was very localized and that all the larvae had been taken within an area of a few square yards. On May 30, Professor Watson visited another infested field at Island Grove, about ten miles south of Hawthorne and collected larvae and pupae. On June 11, it was reported to the author that some insects, supposed to be the Mexican bean beetle, had been observed in the gardens of the College of Agriculture at Gainesville. On visiting the garden it was evident that the beetle had been feeding on some pole and lima beans and a search of

the plants soon produced four beetles and 20 pupae. Another visit on June 26, produced two prepupae, one large larva and two egg masses. At that time there was some evidence of feeding on the beggarweed, *Meibomia purpurea* (Mill.) Vail.

These three infestations, all located in Alachua County, are of interest because they are so far from any other known infestation. Most of the county agents in the northern half of Florida were asked to be on the lookout for the beetle but the nearest infestation thus far reported was the one at Monticello. The air distance from Monticello to the Alachua County infestations is at least 125 miles which seems rather too far for flight by the beetles. The fact that the infested fields at Hawthorne and Island Grove were less than a mile from a main north-south highway much traveled by produce trucks and the Gainesville infestation was within fifty yards of another similar highway may have some significance.

The owners of the infested fields at Hawthorne and Island Grove used insecticides on their beans, apparently with good results since later checks failed to show any evidence of bean beetles. However, no control measures were used on the Gainesville infestation and it too disappeared. Most of the bean plants were dead by the end of June but a flush growth of beggarweed had sprung up and close by was a small planting of cowpeas. Although the beggarweed showed considerable signs of beetle feeding on June 26, when the last insect specimens were taken, later examinations during July failed to show any evidence of beetles feeding nor have any signs of the beetle been seen since then.

All of the known infestations of the beetle have been in the extreme northern and interior portions of Florida, areas which both Marcovitch and Stanley, and Sweetman indicated as probably being unfavorable for the insect. It still remains to be seen how serious it may become if its finds its way into and becomes established in the coastal strip or the southern part of the state which are believed to offer climatic conditions better suited to its requirements.

There are three other records of the Mexican bean beetle in Florida, which do not represent infestations, of this insect but which are interesting nonetheless because they indicate one method by which the beetle has been able to enter the state. The records of the State Plant Board show that on September 7, 1932, J. W. McGlamery captured a bean beetle on top of a cantaloupe

in a store in Coral Gables. Some inquiry brought out the fact that the cantaloupe probably came from New Jersey. On September 29, 1937, Alec White, the county agent in Hillsborough County, sent in to the Experiment Station an imperfectly formed adult bean beetle which had been taken to his office. Careful inquiry indicated that the insect had been found on some green beans in a Tampa market and that the shipment of beans originated at or near Franklin, North Carolina, a region known to be heavily infested by the beetle. On September 23, 1940, H. E. Westbury, the county agent at Palatka, sent a few specimens of the beetle to the Entomology Department of the Experiment Station and wrote as follows: "One of our farmers brought the inclosed beetles to my office this morning and stated he had collected them off of lima and string beans brought in from Georgia and South Carolina at the Produce Market in Jacksonville, Florida." A noteworthy fact in regard to these three collections is that all were made in September when the fall planting of beans is getting well started. If these immigrant beetles had chanced to find their way into suitable bean fields, new infestations could very easily have been started.

No work had been done on the life history of the bean beetle in Florida so an attempt was made to obtain some information on this phase of their biology. The 60 larvae collected May 7, 1942, in the infested field at Hawthorne were placed in a large screen cage in the laboratory. Fresh bean plants or leaves with their stems in water, were placed in the cage as needed to furnish a steady supply of suitable food. Most of the larvae pupated, the first pupating on May 8, and the last on May 10. The 49 adult beetles that were produced emerged during the three day period, May 14-16. Except for the four taken out for individual records, the adults remained in the cage until they died. Two pairs of beetles taken from the cage before egg laying began, were placed in separate cages and a daily record was kept of all eggs produced. One female began egg laying on May 30, laid a total of 1032 eggs in 19 clusters during the oviposition period of 50 days. The other female began producing eggs May 31 and laid a total of 721 eggs in 14 clusters during the oviposition period of 30 days. A second generation female laid her first eggs on August 3, and produced a total of 246 eggs in 8 clusters, during the oviposition period of 18 days.

The eggs hatched in 5-6 days with an average incubation period of 5.6 days for 119 eggs. The larval period varied from

15 to 17 days with an average of 15.2 days for 28 larvae. The total developmental period from egg to adult varied from 24 to 28 days with an average of 25.6 days.

Longevity records were obtained for 55 adult beetles. A few, which were badly malformed died within a day or two of emergence. The greatest length of life was 110 days and the average length of life was 54.5.

Seventy-five per cent of the eggs in the first clusters laid May 31 and June 2 hatched and a fair proportion of the larvae reached maturity. Within a few days the percentage of eggs hatching decreased very rapidly and less than 1 per cent of the eggs laid after June 10, hatched. The larval mortality rose very rapidly and the few that became adult were so badly deformed that they died without producing any eggs. These results appear to explain the natural eradication of the Gainesville infestation and they closely parallel the situation found during hot, dry periods in other parts of the Gulf Region.

SUMMARY

The first known infestation of the Mexican bean beetle in Florida was discovered at Monticello, May 20, 1933. The infestation was eradicated during the summer and there was no further evidence of the beetle in the state until 1938 when a second infestation was found at Havana, in Gadsden County. This infestation has persisted and has caused some damage each year. Other infestations have developed in Gadsden and neighboring counties, and in 1942 three isolated infestations were found in Alachua County, more than 125 miles from any other known infestation. The beetle has not yet become established in those parts of the state presumed to be ecologically better suited to its needs. Life history studies at Gainesville in 1942 showed that the eggs failed to hatch during hot weather, that larval mortality was very high, and that many of the adults produced then were badly malformed.

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WAR AND ITS EFFECT ON THE INSECTICIDE INDUSTRY

R. L. MILLER

(Continued from page 56, Vol. XXV)

NICOTINE COMPOUNDS will probably be available since the supplies are mostly domestic. The demand for such chemicals is very temperamental, depending on seasonal conditions which favor the development of sucking insects; but it is the writer's opinion that supplies of nicotine will be available in sufficient quantity. Black Leaf 155 and Black Leaf 10 have been developed for use as poisons as well as contact materials and in some instances have given excellent results against chewing insects.

PYRETHRUM at one time came largely from Japan but since the quality and uniformity of this product was too often tampered with, more recently the major production has come from Kenya Colony, on the east coast of Africa. Although the product is still available, transportation of such a bulky material over such a long distance will probably restrict the supplies available in the United States. This will be a handicap to the fly spray industry as well as to most vegetable growers. On June 11, 1942, the War Production Board issued Preference Order M-139 on Pyrethrum Flowers which, however, does not specify definite uses but requires that manufacturers using Pyrethrum Flowers get authorization for purchase of supplies from the War Production Board.

ROTENONE is the one example of a very limited supply of an insecticide, on the regulation of the use of which a Government presedent has been set. Conservation Order M-133 restricts and specifies the use of rotenone compounds in the United States in connection with the war effort. If this is an example, and it most likely is, of the method in which other scarce chemicals will be distributed by government order if and when it is necessary, such a regulation can probably be worked out very nicely. In the case of rotenone, its use is prohibited in non-essential places and allowed for the Government or for the production of food crops on which no other insecticide is satisfactory. The rotenone supply comes almost entirely from the East Indies and South America and these sources have been practically cut off.

SULPHUR is almost entirely of domestic production and great supplies are available in Texas. For example, the Texas Gulf Sulphur Co., maintains more than a world year supply above ground at all times. It only remains for us to get sufficient transportation and manufacturing facilities to make available all sulphur products that are necessary.

It will probably be necessary to use sulphur compounds in place of other fungicides or insecticides wherever this is possible and it may be advantageous to exploit the uses of sulphur, as much as possible since large supplies of this are available domestically.

ZINC SULPHATE is available in considerable quantities in the United States although the war effort demands considerable quantities of zinc metal. In 1925 forty per cent of the world's production was produced in the United States. Both zinc oxide and zinc sulphate have been used, although zinc sulphate is by far the most used, in Florida agriculture. This material must be applied as a nutritional spray for citrus and this can be done most effectively during the spring or early summer. It is quite possible that, for a conservation practice, dilute sprays will be necessary annually or occasionally when frenching or zinc deficiency appears.

There are a large group of miscellaneous spreaders, stickers, wetting agents, and emulsifiers which are mostly organic chemicals and are from time to time quite restricted in their supply. It behooves every insecticide manufacturer to have alternate

compounds available which can be substituted for some commodity whose distribution has been restricted by the war effort.

The use of stickers is usually a very advantageous one, particularly when smaller quantities of chemicals will likely be available. Any compound that can be added to improve the effectiveness of one of the essential chemicals should certainly be used.

Considerable experimental work has been done with reduced dosages of many of the essential insecticides and fungicide chemicals with apparently quite satisfactory results. For example, it has been suggested that Rotenone Dust mixtures could be reduced to .5% Rotenone with satisfactory results. The same has been found to be the case with seed treating chemicals, fungicides, and many insecticides. In making recommendations, however, with reduced concentrations, care should be taken to make thorough enough applications so that the reduced toxic ingredients will be effective enough to give satisfactory control.

All entomologists can be of considerable service to growers now in pointing out the first or earliest stages of insect development so that populations can be prevented from building up. Considerably less chemicals are necessary for treating light infestations of small or young pests, whereas much greater amounts of heavier concentrations are necessary after dense populations have been built up.

All that has been said about the scarcity of essential insecticide and fungicide chemicals can be repeated regarding spray and dust equipment. In many cases special metals are used or particular brass or bronze parts are necessary; and these are and will be particularly hard to get.

High pressure spray hose is and probably will be scarce or limited in quantity just as all other rubber products are limited.

Transportation of insecticides and fungicides, as mentioned previously, is a considerable item and the shipment of all commodities is delayed. Growers can facilitate their own business by anticipating their demands as soon as possible and allowing the suppliers of their insecticides and fungicides as much time as possible to make delivery. Calculations as to the amount of material necessary should be very accurately done and request for return of unused products should be made as infrequently as possible. Since the movement of many insecticide and fungicide chemicals was by water, and freight rates were based on water transportation, which has now been discontinued to a

large extent, the cost of shipping coastwise moving chemicals has been increased considerably because of the difference in rail freight and water freight.

Containers for insecticides and fungicides have become more scarce and have increased in price. The supply of 55 gallon steel drums will probably be the greatest handicap of all container problems. Conservation of these drums by users is very essential to their being able to obtain additional supplies of those commodities that are transported in drums. As soon as the drum is empty, it should be returned to the manufacturer from whom it was obtained, in order that additional supplies may be moved.

As stated before, the writer is certainly not magician enough to tell specifically what particular items of insecticides and fungicides will be scarcest or will disappear from the market; but it is our suggestion that, since we are not sure as to the available supply, every effort be made to conserve both chemicals and equipment; and you may rest assured that every effort is being made by manufacturers and suppliers to obtain either the original insecticide and fungicide chemicals or to do sufficient research to establish the use of a substitute product so that the production of crops will not be handicapped.

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SOME PRELIMINARY INVESTIGATIONS OF THE GREEN SCALE, *Coccus viridis* (GREEN), IN SOUTH FLORIDA

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INTRODUCTION

The green scale, *Coccus viridis* (Green), also known as the green coffee scale, soft green scale, and green bug, a pest of citrus and other woody and herbaceous plants, was discovered by grove inspectors of the State Plant Board of Florida near Davie, Florida, during May of 1942. Since then studies have been conducted on the life history, habits, and control of this scale. It is not known how long the green scale has been in South Florida; however, indications are that it has been there for several years.

DESCRIPTION

The name given this scale is very descriptive of its main character which is its color. It is bright pale green, being more or less transparent. The young stages are easily confused with the young of the green shield scale, *Pulvinaria psidii* Mask., but the adult does not have an egg sac outside the body as does the green shield scale and some other soft scales. The outline shape of the green scale is elongate oval and the actual body measurements on citrus are as follows:

Length, from 2.35 mm. to 3.3 mm.

Width, from 1.35 mm. to 1.65 mm.

On groundsel trees, the favorite host, they are only about three-fourths as large as on citrus.

The crawlers and adults have small black eyes and the legs and antennae are light green. On the dorsum of adult scales and those nearing maturity a black U-shaped or irregular internal marking, the closed end of which is at the anterior, is visible to the naked eye. At times this marking pulsates with regular beats varying from 27 per minute in some scales to 45 per minute in others. The movement of this internal marking seems to originate at the closed end of the U and working toward the rear. After the scales die they turn a light brown or buff color and the black markings are no longer apparent.

Green scales appear in a rather definite pattern on citrus leaves. The undersurface of the leaves toward the base is preferred, and the adults sometimes line up along both sides of the midrib, 2 or 3 abreast. On heavily infested citrus limbs as many as 250 to 325 scales per leaf have been found. Infestations were usually spotted on the individual trees; occasionally one-half of the tree was infested and the remainder had few or no scales. All stages of the scales were found infesting immature oranges and immature and mature limes. Although the foliage of grapefruit was often heavily infested, no scales were found on the fruit itself. On groundsels the scales were usually distributed over the entire plant.

KNOWN DISTRIBUTION IN FLORIDA

Indications are that the green scale has been limited to the present time to the extreme lower east coast of Florida. It is known to be established from 5 miles north of Ft. Lauderdale to a few miles south of Florida City.

HOST PLANTS

According to the records of the State Plant Board, this scale has been found on 72 different species of plants in Florida, so it is far from host specific and can reproduce itself on several species of plants in a grove should conditions become too adverse to permit further development on citrus. Apparently the preferred host of this scale is the groundsel tree, *Baccharis halimifolia*. Another common name of this plant is "silverling" and in South Florida it is best known as "glades myrtle." Although several young citrus trees were found to be heavily infested, citrus did not appear to be an especially preferred host. The following plants have been observed by O. W. Calkins, a State Plant Board Inspector, to be more heavily infested than some others on the host list: Groundsel, tropical currant, wild coffee, citrus, sapodilla, buttonbush, guava, ti-es, marlberry, seagrape, poisonwood, goldenrod, *Tetrazygia*, bustic, southern sumac, *Nectandra* sp., banana, *Ixora coccinea*, gardenia, wild primrose and ragweed.

Apparently, heavy infestations of green scales eventually will kill groundsels. This was demonstrated in Davie where several heavily infested groundsels were tagged at random for observations. The trees began to lose foliage and 3 months after the infestation had reached a dense population, the trees were bereft of foliage and some of them were dead to the base.

APPARENT ECONOMIC IMPORTANCE

The green scale in Florida has not been under observation sufficiently long to determine its economic importance. In two groves in Davie only a small percentage of the trees were infested. Since the groves were only 3 to 5 years old, it might be possible that the scales had not been on the trees sufficiently long to build up a heavy infestation. No extremely heavy infestations have been found on large mature citrus trees.

There is evidence indicating secondary damage which may be as severe and perhaps more so than the injury caused by green scales. In Florida and parts of the West Indies it has been observed that the populations of purple and long scales on citrus seem to increase considerably following heavy green scale infestations. According to W. L. Thompson,¹ one of the probable reasons for this increase is the presence of sooty mold that grows on the honeydew which is exuded by green scales. Furthermore, green scales are parasitized by a white-fringed fungus, *Cephalosporium lecanii* Zim., and after this fungus kills the scales, young purple and long scale crawlers hide under these dead mycelia-enveloped bodies. This was observed quite frequently while making counts. Green scales infected with *C. lecanii* will show the mycelium for 30 days, and observations indicate that these fruiting bodies cause the dead scales to stick to the leaves for a much longer period.

LIFE HISTORY AND HABITS

For experimental convenience the stages of green scales were divided into three classes:

1. First stage—all eggs and crawlers under the adults.
2. Intermediate stage—all not included in 1 and 3.
3. Egg depositing adults.

Green scales are parthenogenetic and oviparous. The eggs, whitish green in color and elongate oval in shape, are laid singly

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and remain under the adult until hatched. In hatching the egg case splits at the anterior, leaving the fore appendages free to struggle and work out of the remainder of the chorion which is sloughed off at the posterior. Eggs hatch from a few minutes to several hours after deposited. During September, October, and November 85 or more eggs were deposited per female. Due to *C. lecanii* and other parasitic fungi, considerable variation occurred. There was also a variation in the number of days in which adults deposited; some apparently completed deposition in 8 days, and a few under observation deposited over a 42-day period. In South Florida, the average length of time that passed from the egg to egg-depositing maturity was 59 to 62 days during the late summer months, and variations of from 50 to 70 days occurred.

The number of molts a green scale goes through was not determined; however, 3 different sizes of scales were observed dragging molt skins. According to Miller,² "The larvae in any stage and the mature females as well are able to change their feeding position at any time, and the habit is very noticeable on branches which through any cause have begun to wither. The migration of the scales in search of fresh foliage takes place very soon after withering begins and very few individuals die in their old feeding positions upon such branches."

Miller's statement regarding the mobility of this scale was well substantiated in South Florida by observations made of the frequent migration of scales in search of fresh foliage.

A test was conducted to determine how long green scales would live without food. Some heavily infested groundsel twigs were cut and placed in a paper sack of double thickness. This was then placed in a can which had one inch of water in it. The sack was placed on a block to keep it out of water, and the can was sealed. Six examinations of the scales were made at various intervals and on the twenty-first day one living green scale crawler was observed. The scales that were living near the twenty-first day were not the scales that were living at the beginning but crawlers that had been deposited by adults up to the eighteenth day.

(To be continued)

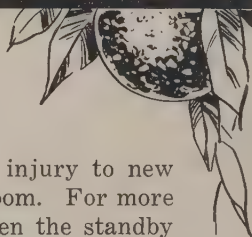
² Miller, 1931. The "Green Scale" of Coffee. Federal Malay States Dept. Agr. Science, Ser. 7.

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No. 2

DATA AND OBSERVATIONS ON THE NATURAL REDUC- TION OF ANOPHELES MOSQUITO LARVAE IN CERTAIN ENVIRONMENTS

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In considering the factors in nature that prevent mosquitoes from becoming abnormally abundant, it becomes quite evident even from superficial observations that many forms of aquatic life play a significant part. Both plants and animals have been designated as important in this capacity, but apparently there is no statistical evidence on the efficiency of predators under natural conditions. Considerable information has been accumulated, however, based on laboratory study and field observations made in disturbed environments, but the activity of predators under such conditions is not a true index of their efficiency as predators within the range of conditions characterizing natural environments.

In view of this fact, a study was made in 1938-39 in permanent water basins in the vicinity of Gainesville, Florida in an attempt to determine the efficiency of biological factors that hold anopheles mosquitoes in check. Precise evidence, as is to be expected in this type of study, was foiled not only by the complexity of the environment, but by the cyclic and abrupt changes that normally occur in water environments, the most significant of which were temperature, increase and decrease in vegetative growth, rainfall, rise and fall of the water level, the action of different predators and factors that influence predator abundance. Never-the-less, the data obtained presents a rather clear-cut picture of what might be expected to occur in anopheles populations in certain ecological associations; and although specific evidence is obscured, mosquito population data and observations on the range of activity, aggressiveness and abundance of predators are considered sufficient to ascertain the principal predators and give a strong indication as to their efficiency.

The forms encountered in this study that were observed to prey on the active immature stages of anopheles include the following: the mosquito fish (*Gambusia affinis*), water scavenger beetle larvae (*Tropisternus* spp.)¹, the top minnow (*Heterandria formosa*), a creeping water bug (*Pelocoris* spp.), a water measurer (*Hydrometra* spp.), a back swimmer (*Plea* spp.), and a water-scorpion (*Ranatra* spp.).

The mosquito fish is an aggressive, ravenous surface feeding species which was prevalent throughout the year in and around vegetation and near the shore line. A definite increase in abundance was noted in mid-April and maintained until mid-June at which time the number began to diminish rapidly, apparently through the action of larger predatory fish.

The water scavenger beetle larva is an aggressive ravenous predator that crawls about just below the surface of water on submerged vegetation in the immediate range of anopheles larvae which are seized and devoured. This form was noted to have become numerous on August 12 and on two occasions in the latter part of August, fourteen specimens were taken in 10 dips; it was still prevalent in early October.

Other predators that occurred within the range of these studies were either scarce or their customary range of activity limited their importance as predators of anopheles. Although the top minnow was abundant and inhabits the upper strata of water, it is considered of secondary importance when in an association with the mosquito fish because it is less aggressive and has more of a tendency to remain among submerged vegetation and feed below the surface of the water. The other species of lesser importance were comparatively scarce in the environments studied and for the most part only their range of activity brought them within the scope of this study.

The greater part of this study was made near the shore of a small lake which will be referred to as Lake Alice, in an area exposed to the sun and characterized by a predominating growth of parrot's feather (*Myriophyllum proserpinacoides*) in the water usually a few feet beyond the shoreline, sedge (*Cyperus strigosus*) and smartweed (*Persicaria punctata*) growing in the water at the shoreline, lesser duckweed (*Lemna minima*) varying in abundance on the surface of the water among the upright

¹ Determined by Frank N. Young, Jr., Biology Department, University of Florida. Adult *Tropisternus* specimens collected were identified as *T. lateralis* and *T. blatchleyi*.

vegetation; greater duckweed (*Spirodela polyrhiza*), floating fern (*Azolla caroliniana*), and pennywort (*Hydrocotyle* spp.)² occurred within the environs of this study, but were not abundant enough to play a significant part. The predators in this area included the mosquito fish and top minnow in abundance and the other predators listed above which occurred only in comparatively small numbers. Both *Anopheles quadrimaculatus* and *A. crucians* were breeding in this area; twenty-six per cent of 315 fourth instar anopheles larvae and eighteen percent of 39 pupae were *A. quadrimaculatus*.

To check against the factors in Lake Alice, data were taken in a small pond which will be referred to as the permanent pond. This pond was in an elongate limestone pit surrounded by pine and deciduous trees and shaded for the most part. It was apparently fed by seepage and contained water except at short intervals in unusually long dry periods. The fauna in the water gave evidence of its permanent nature. Considered from the viewpoint of this study, this pond was characterized by small patches of a heavy growth of a small upright plant, *Globifera umbrosa*, and dense localized growths of *Wolffiella floridana*; a comparatively light growth of lesser duckweed and a few plants of smartweed were present. The heaviest anopheles breeding occurred in the *Globifera umbrosa*. Both *Anopheles quadrimaculatus* and *A. crucians* were breeding in this pond. The predator incidence was about the same as that in Lake Alice with the exception that there were no minnows and water scavenger beetle larvae became very abundant.

The data taken in this study included a separate count of the anopheles in each active stage in each successful dip of water. Ten or twenty dips were taken in checking the population and an effort was made to dip from all types of places within the area. Checking was timed in an effort to catch each stage at its height in population within a developmental cycle. Other data taken included the temperature of the water and the rise and fall of the water level. Notes were made on the fluctuation in predator population, their habits and aggressiveness, and the variations in the vegetation.

The data presented in Table I, taken in the permanent pond in the latter part of May, is a type example of data obtained from

² Specific determinations of these plants were made by Miss Lillian E. Arnold and Mr. Erdman West of the Botany Department, University of Florida.

a study made at a time when mosquito breeding and the predator factor was at low ebb and the temperature of the water was relatively moderate and almost constant, ranging between 25 and 26° C. It will be noted that the total number in each larval stage increased with each advanced stage and is less in the pupal stage. This is to be expected because of the fact that a longer time is required to pass each successive larval stage and a shorter time is required in the pupal stage; thus, the time factor accounts for the greater or less accumulation in any particular stage.

TABLE I.—PERIODIC INCIDENCE OF THE DIFFERENT STAGES OF ANOPHELES IN THE PERMANENT POND IN MAY, 1939.
(10 dips made in each check)

Date Checked	19	24	26	28	Total Number Collected
Stage	Number Collected				Collected
First Instar	2	3	3	4	12
Second Instar	7	2	6	2	17
Third Instar	7	7	6	4	24
Fourth Instar	3	8	13	7	31
Pupa	0	1	3	4	8

The data presented in Table II, taken in the permanent pond during August, reveals the effectiveness of water scavenger beetle larvae in reducing anopheles incidence under certain conditions. The temperature of the water at the time these data were taken ranged between 25 and 27.5° C.

TABLE II.—PERIODIC INCIDENCE OF THE DIFFERENT STAGES OF ANOPHELES IN THE PERMANENT POND IN AUGUST, 1939.
(10 dips made in each check)

Date Checked	5	9	10	12	13	15	17	19	21	23	Total Number Collected
Stage	Number Collected										Collected
First Instar ..	12	56	97	162	114	54	78	94	96	66	829
Second Instar	11	12	22	53	70	92	76	48	80	60	524
Third Instar	13	12	7	16	24	19	78	39	24	24	256
Fourth Instar	5	9	19	9	7	8	17	29	40	11	154
Pupa	0	2	1	6	4	2	1	2	7	11	36

This data shows the gradual population build-up in each stage and the peaks of abundance which came in the first instar between the 10th and 13th, in the second instar between the 13th and 17th, in the third instar between the 15th and 19th, in the fourth instar between the 19th and 23rd, and the peak of pupal incidence occurred between the 21st and 23rd. The sum of the three figures within the peak range of each stage corresponds in ratio almost exactly in every instance with the percent population decrease indicated in the total column. Without accounting for the developmental time factor which on the basis of the data in Table I would account for an increase of 11% in predatory evaluation in this case, this data indicates an 81% decrease during larval development with a marked reduction in each stage. Never-the-less, the biotic potential under these conditions was high enough to overcome this increased natural resistance as indicated by the number of mosquitoes reaching the pupal stage. This series of data was terminated by a heavy rain which inundated the pond.

TABLE III.—PERIODIC INCIDENCE OF THE DIFFERENT STAGES OF ANOPHELES IN LAKE ALICE IN DECEMBER, 1938 AND JANUARY, 1939.
(20 dips made in each check)

Date Checked	Dec.		Jan.				Total Number Collected
	19	26	2	9	16	23	
Stage	Number Collected						
First Instar	94	11	10	8	16	12	151
Second Instar	28	42	22	6	17	13	128
Third Instar	32	19	47	11	7	13	129
Fourth Instar	26	21	16	23	24	12	122
Pupa	0	1	2	2	3	3	11

Data presented in Tables III, IV and V represent a part of the data taken in the studies made in Lake Alice. Table III includes data taken at weekly intervals from December 19, 1938 to January 23, 1939. The range of the water temperature is indicated by records taken in January which was 18° on the 16th and 17° C. on the 23rd. A peak in population occurred in each successive stage at weekly intervals, indicating four or five weeks as the time required for larval development. The actual totals in this data indicate a larval decrease of only 19%, but because of the low temperature range and time involved there is

no tangible basis on which this data can be interpreted. An unusual number of pupae and pupal skins noted in the latter part of this series indicates, however, that many representatives were completing development, and the extended time of exposure to predators is sufficient evidence to establish the indication that predator efficiency was comparatively low during this period.

Table IV represents data taken in mid-April when the minnow population had shown a considerable increase. The recorded temperature of the water indicates that it ranged between 28 and 29° C. A peak in population of each successive larval stage was obtained by checking every other day; the peak in population for the pupal stage was obtained on the third day after the peak obtained in the fourth instar which indicates that the maximum fourth instar population probably occurred after the 16th, but the data taken on the 17th showed only fifteen fourth instar larvae and no pupae. The number of forms in the second instar on the 10th indicates that the peak in the first instar was taken on the decline; although no data were taken to substantiate this indication, it may be assumed on the basis of other series of data. These data indicate a 40% larval reduction with the greatest reduction apparently involving the third and fourth instars which may be considered erroneous if it is assumed that the peak obtained in the first instar was on the decline. If this assumption is correct, the actual reduction during this period should be greater than is actually shown. The pupal incidence indicates that a considerable number were able to complete development which in such a large breeding area would result in a relatively high incidence of adults.

TABLE IV.—PERIODIC INCIDENCE OF THE DIFFERENT STAGES OF ANOPHELES IN LAKE ALICE IN APRIL, 1939.
(20 dips made in each check)

Date Checked	10	12	14	16	19	Total Number Collected
Stage	Number Collected					Total Number Collected
First Instar	35	18	5	7	5	70
Second Instar	21	31	20	7	6	85
Third Instar	7	18	23	13	9	70
Fourth Instar	6	5	9	16	6	42
Pupa	0	1	3	1	5	10

Table V presents data taken during May when the minnow population had apparently reached its height in activity and population. The records of the temperature of the water ranged from 24 to 34° C. The peaks in larval populations can be followed through fairly well in the first part of the month which indicates that about seven days are required for larval development. All the population data taken during May are given to show its consistence since totals in the table give essentially the same percentage larval reduction as the totals of the data including only that within the developmental cycle. These data indicate a larval reduction of about 87% with the greater part of the reduction shown in the third and fourth instar populations. The consistently low figures in the fourth instar and the scarcity of pupae indicate that the number of forms completing development is insignificant during this period.

TABLE V.—PERIODIC INCIDENCE OF THE DIFFERENT STAGES OF ANOPHELES IN LAKE ALICE IN MAY, 1939.
(20 dips made in each check)

Date Checked	1	3	5	7	9	11	13	17	19	24	26	28	Total Number Collected
Stage	Number Collected												
First Instar	49	31	28	17	7	10	17	12	12	18	11	11	
Second Instar	12	29	13	20	10	11	7	15	13	15	22	14	
Third Instar	6	4	10	12	11	8	5	7	6	3	4	9	
Fourth Instar	1	0	2	8	4	3	3	3	2	0	3	0	
Pupa	0	0	0	0	0	0	1	0	1	1	0	0	3

Anopheles breeding continued in Lake Alice from mid-June through August at such a low ebb that many tries were necessary to obtain a minimum of ten successful dips, and of the forms collected, very few had developed beyond the third instar. The temperature of the water during this period ranged up to 38° C. Temperature was apparently the predominant factor keeping anopheles incidence low in this water during this period.

These data and observations indicate that the degree of predator efficiency on anopheles breeding in permanent water basins varies with the season and predator abundance. The mosquito fish was the principal predator in an association which included many other common predators; water scavenger beetle

larvae became the principal predator in an association in which no minnows occurred.

This study indicates that the mosquito fish is a dominating species. It is apparent that its efficiency as a predator of anopheles increases with the increase in size of mosquito larvae, but its efficiency in associations where protective vegetation and debris occur is dependent to a marked degree on the activity of other aquatic life both beneath and on the surface of the water. This becomes evident because an undisturbed form, floating at the surface of water against an object, is not likely to be detected by minnows unless exposed by its own movements. Unlike the mosquito fish, the efficiency of the water scavenger beetle larva is dependent upon the habit of anopheles remaining immobile at the surface of water in contact with vegetation or some other floating object and its efficiency is apparently not affected by the size of its prey; thus accounting for the independent efficiency of this form as a predator of anopheles.

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